

Earthquake Prediction and Earthquake Damage Prediction

John Bramlet

Geological Sciences, Ohio State University

Senior Thesis Spring 1996

Allan C. Hoffman

Table of Contents

Abstract	1
Brief History of Earthquake Prediction	1
Recent Large Earthquakes in California	6
Earthquake Damage Prediction	8
Figures to Mitsui Fudoson	
Worksheet	16 - 17
IRAS Results for Mitsui Fudoson	18 - 22
ISO Building Classification	24 - 26
Factors Affecting Intensity	27
Damage Ratio Curve	28
ISO Earthquake Susceptibility Zones	29
Los Angeles Fault Map	30
San Francisco Fault Map	31
References	32 - 33

Earthquake Prediction and Earthquake Damage Prediction

John Bramlet

Abstract

Earthquake prediction is slow in development. We are still far from making accurate predictions. The latest seismic prediction scheme, the VAN method, is promising, but most scientists are still skeptical. On the other hand, recent earthquakes in California have revealed much information on earthquake damage. Building construction, over the past few decades has continuously improved, and dramatically decreased damage done by earthquakes. It is as important to be able to predict earthquake damage as it is to predict earthquakes. IRAS is a sophisticated computer program used by the insurance industry to estimate expected damage on property.

Brief History of Earthquake Prediction

The 1970's was a revolutionary period for the field of seismology and earthquake prediction. One of the most important dates in the field of earthquake prediction may be February 4, 1974, the date of the Haicheng Earthquake in China. Haicheng is a town located in Liaoning Province, in

northeast China, 50 km from the coast. This earthquake was supposedly predicted by scientists in China. During the 1970's, China remained isolated from the outside world, so evidence of this "prediction" got much more attention than it deserved. Nonetheless, just as the USSR's space program captured America's attention, this advancement by the Chinese also captured the attention of western scientists.

Today's history of the Haicheng prediction paints a much different picture than the one that was believed during the 1970's. The belief was the Chinese were able to accurately forecast the earthquake, and evacuate the area to avoid a catastrophe. In reality, this is far from true. The quake was not officially forecasted until 12 midnight on February 4, while the main shock occurred at 7:36 PM on the same day. This prediction was made after a series of foreshocks were monitored in the Haicheng area, at the rate of 500/hour.

Much of the knowledge of the geology in Liaoning Province was gathered in surveys set up in 1971. It was known that uplift existed in the Korean Bay. Earthquakes were common in the area, and the Chinese leadership was frantic about being able to predict quakes, for the country has a history of devastating earthquakes. Bench marks were set up to measure creep. These were simply sticks placed in the ground, and spacings were measured at periodic intervals. In 1974, there was a 4 mm increase in creep relative to that seen in previous years. This creep was seen as an increase in elevation, and was coupled with an increase in seismic

activity. This is the extent of the background information that the Chinese scientists had.

The Chinese were concerned with predicting quakes, but they were not concerned with predictions that didn't occur. This led them to issue predictions under any circumstance to please the government, and thus diminished their significance. The so-called evacuation of the city is false. Although many residents left their homes, it was a result of the foreshocks in the morning. Many returned to their homes in the evening for dinner, only to have the main shock collapse their home on top of them. 1,328 people were killed in the quake.

In 1977, the United States Congress passed the National Earthquake Hazards Reduction Act (NEHR). This gave the USGS the appropriations to organize an earthquake prediction program. The Haicheng "prediction" was behind much of this new motivation to predict earthquakes. By 1982, the USGS had made little headway in the area of prediction, and Congress suggested that the NEHR may need to be reorganized. Some, less-scientific minded, members of congress suggested giving the NEHR to NOAA, since earthquake prediction can't be much different than predicting the weather. In 1983, the USGS launched the Parkfield Project, partially in response to these threats.

The Parkfield Project, (based on a 1985 paper by Bakun and Lindh), forecasted an earthquake of magnitude 5.5-6.0 near Parkfield, California (southern CA), with a window of

five years before and after 1988. The basis for this bold prediction was quite simple. The basic idea is that earthquakes will occur at the same places on a fault, at regular intervals, and thus this recurrence time is predictable. The Parkfield earthquake was predicted on 6 dates of recorded earthquakes in the years: 1857, 1881, 1901, 1927, 1934, and 1966. The recurrence time for these earthquakes is 24, 20, 21, 12, and 32 years respectively. The average for these five recurrences is 21.8 years, and this is where the prediction was made. 1966, plus 22 years is 1988, and the margin of error is computed from the standard deviation of the recurrences. The bases for this prediction was based on statistics, and not geology.

It is not hard to find flaws with the Parkfield forecast. Any statistics based on five data points, that are as widely distributed as these, will yield poor results. For instance, if the 1966 earthquake were to be predicted with the preceding 4 earthquakes, it would have been missed by 13 years.

While scientists were patiently awaiting the Parkfield earthquake, a major quake struck in northern CA, far from Parkfield. On October 17, 1989, during the World Series, the Loma Prieta Earthquake ($M=7.1$) killed 68 people in the San Francisco area. This shattered the Parkfield prediction. This earthquake was nowhere near Parkfield, and it came as a surprise. No predictions were made for the Loma Prieta Earthquake.

The latest research on earthquake prediction is centered around the VAN method. Van is an acronym for three Greek scientists, Varotsos, Alexopoulos, and Nomikos. These scientists predict earthquakes by measuring magnetic fields. These magnetic fields may change, signaling a seismic event. According to Science (1995), "Fracturing rock generates a transient electrical current as crystal imperfections cause a separation of charge." Perhaps the movement of pore water is the cause of these signals. In the experiment, a system of measuring stations is set up, each with a N-S oriented sensor, and a E-W oriented sensor. These stations continuously monitor the natural electrical signals coming through the ground. A strong seismic event will cause a deviation in this normal background current that is measured. There are many factors that go into the magnitude of this deviation, such as type of rock, and strength of fracture. Only strong seismic events cause a strong enough electrical deviation that can be distinguished from background noise.

According to Varatos, 10 out of 11 earthquakes were successfully predicted in the past 9 years. The success of the VAN method must be considered with caution. The predictions are vague. They only specify location within 100 miles, magnitude to .7, and timing to several weeks. For a prediction to be any good, it needs to be more precise than this. Nonetheless, these predictions are far from lucky guesses, and it is something that is worth further. There have also been magnetic disturbances measured in US quakes.

According to Stanford University's Antony Frasier-Smith, unusual magnetic activity occurred before the Loma Prieta Earthquake. Magnetometers placed on the San Andreas fault revealed a magnetic disturbance following a M=5.9 earthquake in 1986, in North Palm Springs, CA.

Recent Large Earthquakes in California

On June 28, 1992, the Landers and Big Bear earthquakes struck southern California. The Landers Earthquake (M=7.4) was the strongest earthquake to strike California since 1952. It was located on the Camp Rock-Emerson Fault. This quake, which occurred at 4:58 AM, triggered the Big Bear Earthquake (M=6.5), at 8:05 AM on the same day. The Big Bear Earthquake occurred on a previously unknown fault, which intersects the Camp Rock-Emerson fault. A 43 mile surface trace was formed by the Landers quake. Much of the faulting was located in a zone, rather than a clearly defined trace. About 25% of this faulting was located on previously unknown faults. This powerful earthquake dispelled a myth that powerful quakes won't occur on unknown, minor faults.

Due to the earthquakes' remote location, little new information was learned from the damage. The hardest hit towns were Landers, Yucca Valley, and Joshua Tree. Much of the damage was done to unreinforced masonry (URM) construction. In the Big Bear Lake area, 2,600 chimneys were knocked down. Falling chimneys can do substantial damage to the rest of the building. Other common damage that was seen,

even in reinforced masonry structures, was damage to the wall-roof connections, and the foundation-wall connections. During a powerful quake, parts of a building will move in different directions, and if these connections are not strong enough, they will shear, causing severe structural damage. Much of the damage was confined to homes. Homes built with light wood frames, were built under a special building code, which eliminated the requirement for any structural engineering analysis. The result of this building code was seen through the heavier damage in these buildings.

No structural damage was done to buildings in the Los Angeles area, although the earthquake was strongly felt there. The quake was strong enough to due cosmetic damage, such as knock things from shelves, as far as 100 miles away. There are reports of the quake being felt by people as far away as Richfield, Utah.

The most recent major quake in California was the January 17, 1994, Northridge Earthquake (M=6.7) in the Los Angeles area. The earthquake produced the most damage in the US since the great 1906 San Francisco Earthquake. The quake occurred beneath the northern San Fernando Valley, approximately 18 miles NW of Los Angeles, on a blind thrust fault. Much new information was learned from this earthquake.

The most disturbing fact was, just as in the case of Landers, the earthquake occurred on an unrecognized subsurface thrust fault. This earthquake demonstrates the complexity of the faulting of the area, and the fact that

earthquakes don't occur where their 'supposed' to. This blind thrust fault is buried, with no surface trace, so there was no way to have known about it. Furthermore, the 1971 San Fernando Earthquake, located in the same area, was situated on a fault with a near opposite fault-plane orientation.

The pattern of damage, although greater, was similar to Loma Prieta and Landers. Reinforced buildings that met current earthquake code fared well, and older structures were usually severely damaged. Collateral damage was also demonstrated in the form of landslides in the San Gabriel and Santa Susana Mountains. A more interesting problem was the illness produced by the inhalation of the *Coccidioides* fungus, whose spores were stirred up by the earthquake.

Earthquake Damage Prediction

The insurance industry is very much concerned with earthquake prediction, and earthquake damage prediction. The industry uses a rating scale for each piece of property. The two main risk factors are geographic location, and type of construction involved. The basis for earthquake policy in the United States, is based on the ISO Earthquake Susceptibility Zones. This map, which was designed in 1985, is used throughout the insurance industry. The US is divided into regions according to there earthquake damage potential on a scale of 1 to 5. The highest risks (1), are located in California, Alaska, and western Nevada. For regions in

susceptibility zone 1, an individual property assessment is done to assess the total risk involved, and an individual rate is issued. In regions 2 through 5, there is usually one specific rate, and there is no individual assessment of the property. For example, property in Minnesota is not given the same kind of attention as a property in California.

Risk Management Software, Inc. is a company that writes computer programs used in the insurance industry to estimate the probability of loss for any specific property. The Insurance Risk Assessment System (IRAS), was originally developed at Stanford University. It covers a range of natural disasters, including wind, fire, hurricane, volcanic eruption, and earthquake.

The program has an abundance of built in information. After the property location is inputted, the program can immediately tell the user information such as the proximity of major and minor faults, the geologic history along these faults, topography, hydrogeology and superficial geology of the area. The user can manipulate this information, input it directly, or just use the information provided by the database.

Soil type, for example, can be described as firm soil or bedrock, shallow alluvium, deep alluvium, bay mud or artificial fill, or unknown. Much of the LA area is overlain by shallow or deep alluvium, such as the San Fernando Valley. The famous Marina District, in San Francisco, is sitting on top of an old dumpsite, which is all artificial fill. A firm

soil, or bedrock provides the best geologic foundation. These other 'softer' soils cause an amplification of the earthquake's destructive waves. The landslide and liquefaction information can be inputted by the user. Landslides are a common occurrence in California, especially during a period of wet weather. An earthquake can trigger a landslide, so it is important to calculate a basic landslide probability. Property located on a side of a hill, or at the base of a mountain will have the highest risk for landslide. Liquefaction is caused during earthquakes. The ground water is forced out of the ground, causing the ground to liquefy, and become mud. This could affect the integrity of a foundation.

IRAS contains 227 seismic sources (faults) in the state of California, 8 in Utah, 12 in Washington, and 33 for the New Madrid area. For each, there is a database of it's return period, maximum possible event, and annual occurrence rate for any event. This database is based on historical record, and local geology. The user has the ability to specify a specific fault, or even an area along that fault, and IRAS will display information regarding that locality. Of course, the location can simply be entered, and IRAS will automatically display what faults must be dealt with.

A seismic attenuation model is employed by IRAS, to calculate the amount of seismic energy, in the form of ground motion. The two factors involved in the calculation of ground motion are the distance from the source, and the local

geology and soil conditions. IRAS uses the Modified Mercalli Scale in calculating the Peak Ground Acceleration (which is measured in g's), since there is more information available through the Mercalli Scale.

Although IRAS has a grand database of geologic information, it is most desirable that the geologic information be entered into the program, rather than depend on the database. In most instances, an on-site inspection is done, for that is the only sure way in determining the property's characteristics.

The second part of the program deals with the construction of the structure. There are three classification schemes that IRAS uses to classify structures. The standard scheme is the ISO Earthquake classes, which is divided into 17 classes. The ATC-13 classes, which is more specific for IRAS, uses 40 building classes. The third class is ISO fire classification, which, unlike the other two, isn't concerned with the buildings structure. Since fire is typical in earthquakes, the fire resistance of a building is very important, and thus, it deserves it's own classification system. IRAS is best used with ATC classes, for the questions it asks are based on the ATC-13 building classes.

There are many features that will decrease a buildings performance in an earthquake. IRAS goes through a basic list for every building, as the user inputs what is known about the structure. The experiences of Northridge are an example as to what construction types, or features are the most, or

least desirable. The three big categories of damage in the Northridge quake are the following:

1. Older structures that don't meet current earthquake code.
2. Tilt-up buildings such as overpasses and parking garages, with inadequate connections.
3. Buildings with a "soft" first story.

The most important information on a structure is it's design code, which is related to the date of construction. Building design and code has been constantly improving. Structures built after 1975 are much better designed against earthquakes. IRAS takes care of this when the user inputs the buildings construction date.

A story profile is determined in how weak or strong the first story of a building is. The Northridge quake showed some startling examples of buildings with a collapsing "soft" story. A "soft" story is a first story that is extremely tall, and/or not structurally reinforced. A large open area, without columns on the first story would be soft. The first story of a building is the most important, and is often responsible in deciding the outcome of a building during a strong quake. IRAS specifically asks if a building has a "soft" first story.

Tilt-up construction, and basic column-beam construction has a serious problem when there is no significant reinforced connections between the columns and beams. This was especially evident in the Northridge, and Loma Prieta Earthquakes. The collapse of I-5 was a result of inadequate structural support between the columns and elevated roadway. Parking garages were hard hit. The columns simply came disconnected from the beams they were holding up. The beams and columns might be reinforced, but if the connection is not sound, it makes no difference. IRAS takes these kinds of constructions into account. Pre-1973 buildings may not have special connections that are now required. Many older buildings have been retrofitted to conform to today's standards.

URM (unreinforced masonry) is another major cause of damage. Many older buildings have had unreinforced masonry retrofits, which is a bracing for these masonry walls. URM is commonly seen on older homes with chimneys. Chimneys don't last in an earthquake. Most of the buildings in the Mexico City earthquake were URM buildings. They collapsed easily.

There is a list of many other factors, which pertain to specific circumstances. IRAS asks questions about adjacent buildings, foundation engineering, duress, construction quality, nearby hazards, ornamentation, and overhangs.

The final step in the program is converting the net energy that has been calculated, into probabilistic damage for the specific type of structure that has been inputted.

The program will come up with a probability damage curve for based on the information it has been given. There are two models used in finding this damages curve. The Probable Maximum Loss (PML), and the Stanford Damage Table (SDT), can be selected. They will give slightly different damage curves. The PML is the older of the two, and is based on historical record, and passed insurance claims. The SDT is the more modern of the two, and is recommended for IRAS.

It is important to note that in the US, any extraneous event that is a result of an earthquake is still considered to be covered by earthquake insurance. This liberal interpretation is part of the reason that so many factors are analyzed in coming up with earthquake damage prediction. For instance, a gas line breaking and starting a fire during an earthquake would be covered. So would be flood damage, if an earthquake caused a tidal wave that hit a property. In Japan, earthquake coverage has a very narrow interpretation. A house that burned down in a fire caused by the Kobe earthquake will be covered if the owner has fire insurance, but should they only have earthquake coverage, there will be no coverage.

The final result of IRAS is much simpler looking than the process of inputting the data. The following is an example of the probabilities that are arrived at. The insured building, owned by Mitsui Fudoson, is located at 505 Montgomery Street in downtown San Francisco. It's building class is ISO EQ 4C, which is basically a steel frame, reinforced masonry building. It was built in 1988, and is a

25 story office building. The location is enough for IRAS to compute all geologic hazards, since it is in downtown San Francisco. The total value of the building is computed by adding the building cost (\$50,000,000), plus the contents (\$25,000), plus the time element, which is the business interruption cost (\$11,203,500), for a total value of \$61,228,500.

The IRAS program uses this information, and computes a worse case scenario. The worst case scenario that is calculated is from a magnitude 8.3 earthquake on the San Andreas Fault. The probability of this worse case scenario, in one year, is only 0.01754%. The expected loss for this worse case scenario is \$24,098,860, which is 39% of it's total value. The insurers loss is calculated by subtracting the first \$12,043,628 of damage, which is not covered under the policy, and \$2,499,514 , which is a 5% deductible, from the total damage. The insurers gross loss is \$9,544,232. IRAS computes a new probability for lesser magnitude quakes on this fault, and other faults. The cumulative probability is the probability of the specified event or worse may occur. The cumulative probabilities rise, as more and more scenarios become possible, and more faults become involved. The resulting damage, however, is less.

EARTHQUAKE INFORMATION - SPECIFIC RISK

- TO BE COMPLETED FOR EACH COVERED LOCATION -

ACCOUNT NAME Mitsui Fudisan

LOCATION ADDRESS: 505 Montgomery Street
Number Street

San Francisco, CA 94111
City State Zip code

POLICY NUMBER AND MOD PAC 89150-25 EFFECTIVE DATE 11/1/96

PROPERTY VALUES/LIMITS AT LOCATION

BUILDING: 50,000,000

CONTENTS: 25,000

TIME ELEMENT: 11,203,500

Bm. Interruption 61,228,500

EARTHQUAKE LIMIT AT LOCATION

BUILDING:

CONTENTS:

TIME ELEMENT:

\$10,000,000 Sublimit
Loss Limit

EARTHQUAKE DEDUCTIBLE AMOUNT: 5% of value

IS DEDUCTIBLE PER LOCATION OR AGGREGATE? Location

EARTHQUAKE ATTACHMENT POINT IF GAI COVERAGE IS EXCESS: NA

EARTHQUAKE INFORMATION - SPECIFIC RISK

- TO BE COMPLETED FOR EACH COVERED LOCATION -

REINSURANCE AMOUNTS ON EARTHQUAKE - LIMITS/PERCENTAGE

TAISHO:

FACULTATIVE REINSURANCE:

OTHER:

CONSTRUCTION INFORMATION

BUILDING CONSTRUCTION: *4C*

(USE ISO EQ CONST CLASSES)

BUILDING AGE: *1988*

NUMBER OF STORIES:

OCCUPANCY: *office*

ANY PARTICULAR BUILDING CHARACTERISTICS THAT WOULD CONTRIBUTE TO OR MINIMIZE EARTHQUAKE DAMAGE:

EXAMPLES:

SOFT STORY -

OVERHANGS -

EARTHQUAKE RESISTANT CONST. - *NA*

FATIGUE-

CONSTRUCTION QUALITY -

HAZARDOUS EXPOSURES -

Earthquake Account Result

12/7/1995, 7:26

Exposure Information

Account Identifier:

QUOTEEQ

Account Name:

MITSUMI FUDOSAN SAN FRANCISCO

Locations Count:

1

Hazard Information

Analysis Option:

Maximum Credible (All)

Analysis Mode:

Distributed

Financial Perspective:

Ground Up

Analysis Currency:

USD

Fault Number, Name:

25 San Andreas N3

Magnitude:

8.30

Return Period:

759 years

Financial Perspective

Amount

Total Value

\$61,228,500

Total Exposure

\$61,228,500

Expected Loss

\$24,098,860

Specified Loss

\$24,098,860

Underlying Coverage Loss

\$0

Insured Loss

\$2,499,415

Other Insurer's Loss

\$0

Loss Above Limit

\$12,055,213

Insurer Gross Loss

\$9,544,232

Facultative Reinsurance Loss

\$0

Quota Share Loss

\$0

Surplus Share Loss

\$0

Working Excess Loss

\$0

Insurer Net Loss

\$9,544,232

Reinsurance Loss

\$0

Earthquake Account Exceeding Probability Results

12/7/1995, 7:29

Exposure Information

Account Identifier:

QUOTEEQ

Account Name:

MITSUI FUDOSAN SAN FRANCISCO

Locations Count:

1

Hazard Information

Analysis Option:

Exceeding Probability

Analysis Method, Mode:

SDT Distributed

Selected Perspective:

Insurer Gross

Analysis Currency:

USD

Threshold Percent:

1.39 %

Threshold Amount:

\$8,939,918

100 year return period

Time Window:

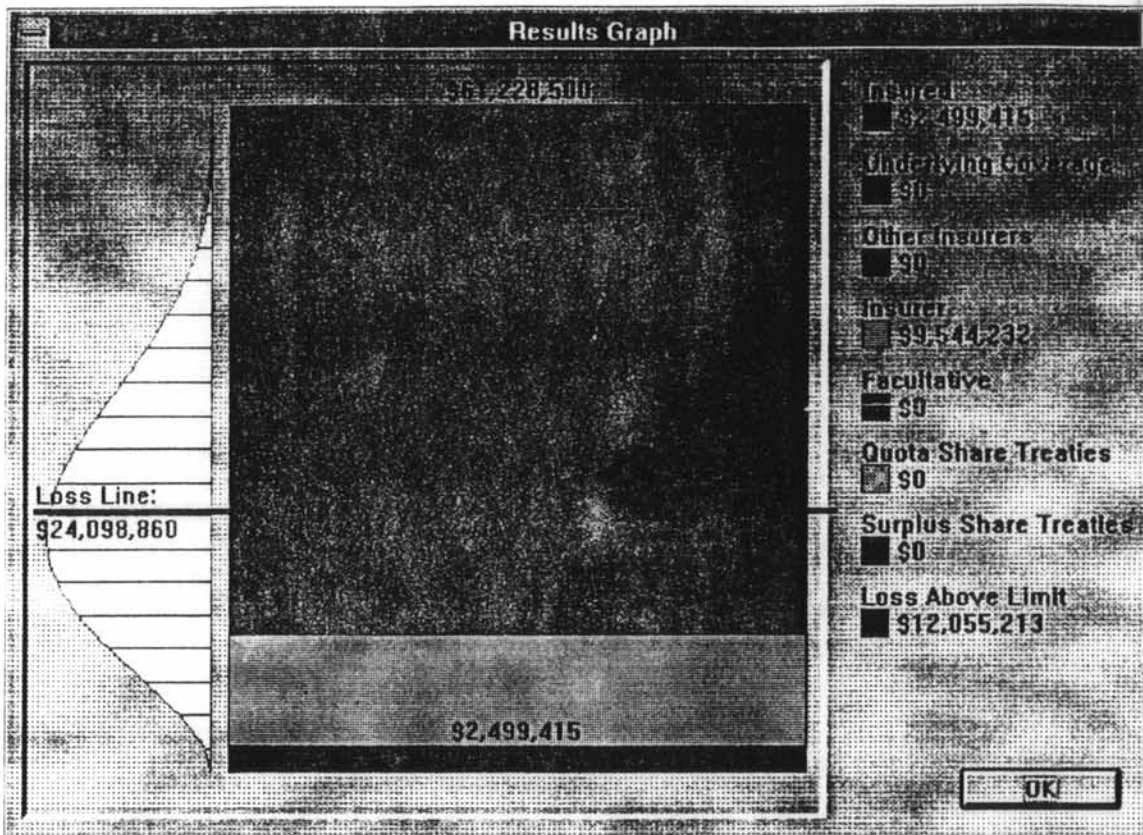
1 years

GAE

Fault	Magnitude	Loss	Probability	Percent	Cumulative Probability
25	8.30	\$9,544,232	0.01754%		0.01754%
25	7.80	\$9,365,088	0.07405%		0.09158%
25	7.30	\$9,164,237	0.26827%		0.35961%
8	7.50	\$9,158,239	0.44275%		0.80076%
8	7.00	\$8,939,918	0.59723%		1.39321%
25	6.80	\$8,608,292	0.17848%		1.56920%
8	6.50	\$6,216,529	0.35345%		1.91710%
25	6.30	\$5,137,414	0.13304%		2.04759%
25	6.30	\$4,922,038	0.13304%		2.17790%
8	6.50	\$4,793,043	0.35345%		2.52365%
3	7.50	\$4,199,134	0.34274%		2.85774%
25	6.80	\$3,421,468	0.17848%		3.03112%
3	7.00	\$3,277,322	0.15349%		3.17995%
25	6.80	\$3,253,923	0.17848%		3.35275%
9	7.50	\$3,174,622	0.34219%		3.68347%
16	7.00	\$2,727,833	0.52892%		4.19291%
8	6.00	\$2,709,627	0.32813%		4.50728%
8	6.00	\$2,656,688	0.32813%		4.82062%
9	7.00	\$2,564,561	0.46158%		5.25995%
8	6.00	\$2,532,841	0.32813%		5.57081%
25	6.30	\$2,524,675	0.13304%		5.69644%
25	6.30	\$2,399,250	0.13304%		5.82190%
25	5.80	\$2,235,562	0.12344%		5.93815%
25	5.80	\$2,187,485	0.12344%		6.05427%
24	8.30	\$2,152,510	0.02110%		6.07408%
25	5.80	\$2,131,774	0.12344%		6.19003%
24	7.80	\$1,837,971	0.07589%		6.26122%
8	6.00	\$1,756,008	0.32813%		6.56880%
11	7.00	\$1,703,071	0.80319%		7.31923%
24	7.30	\$1,562,424	0.13413%		7.44355%
25	5.80	\$1,526,903	0.12344%		7.55780%
25	5.80	\$1,416,441	0.12344%		7.67191%
32	7.10	\$1,415,986	0.00000%		7.67191%
3	7.00	\$1,402,815	0.15349%		7.81362%
10	7.00	\$1,311,167	0.80319%		8.55406%

3.	6.50	\$1,302,744	0.11925%	8.66310%
22	7.50	\$1,277,695	0.03324%	8.69346%
3	7.00	\$1,273,211	0.15349%	8.83361%
22	7.00	\$1,193,655	0.02494%	8.85634%
16	6.50	\$987,308	0.35451%	9.17946%
9	6.50	\$925,012	0.35429%	9.50123%
3	6.50	\$687,680	0.11925%	9.60915%
8	6.00	\$652,656	0.32813%	9.90575%
25	5.80	\$647,713	0.12344%	10.01696%
25	6.30	\$642,045	0.13304%	10.13667%
25	6.30	\$551,445	0.13304%	10.25622%
25	5.80	\$546,465	0.12344%	10.36701%
3	6.00	\$412,609	0.13029%	10.48379%
16	6.50	\$404,151	0.35451%	10.80113%
24	6.80	\$347,163	0.13385%	10.92053%
3	6.50	\$326,115	0.11925%	11.02675%
9	6.50	\$325,565	0.35429%	11.34198%
24	7.30	\$309,864	0.13413%	11.46089%
16	6.00	\$295,067	0.41140%	11.82514%
3	6.00	\$282,458	0.13029%	11.94002%
9	6.00	\$264,896	0.41114%	12.30207%
25	5.80	\$263,714	0.12344%	12.41032%
10	6.50	\$259,351	0.53661%	12.88034%
32	6.60	\$232,120	0.00000%	12.88034%
25	5.80	\$209,364	0.12344%	12.98788%
25	6.30	\$206,280	0.13304%	13.10364%
25	6.30	\$176,728	0.13304%	13.21925%
3	6.00	\$174,469	0.13029%	13.33231%
3	6.50	\$155,138	0.11925%	13.43566%
16	6.00	\$144,093	0.41140%	13.79178%
24	6.80	\$128,741	0.13385%	13.90717%
9	6.00	\$128,614	0.41114%	14.26113%
25	5.80	\$124,677	0.12344%	14.36697%
3	6.00	\$121,874	0.13029%	14.47854%
10	6.50	\$121,496	0.53661%	14.93746%
11	6.50	\$118,975	1.07322%	15.85037%
3	6.50	\$113,914	0.11925%	15.95072%
25	5.80	\$112,007	0.12344%	16.05447%
16	6.00	\$106,198	0.41140%	16.39982%
24	6.30	\$105,422	0.09675%	16.48070%
3	6.00	\$97,369	0.13029%	16.58951%
3	6.50	\$94,084	0.11925%	16.68898%
9	6.00	\$93,304	0.41114%	17.03150%
25	5.80	\$87,593	0.12344%	17.13392%
16	6.00	\$83,337	0.41140%	17.47483%
22	7.00	\$82,854	0.02494%	17.49541%
10	6.00	\$82,022	0.49509%	17.90388%
3	6.50	\$81,513	0.11925%	18.00178%
24	6.30	\$80,530	0.09675%	18.08111%
25	5.80	\$79,727	0.12344%	18.18224%
32	6.10	\$79,622	0.37164%	18.48631%

3.	6.00	\$75,162	0.13029%	18.59251%
9	6.00	\$72,575	0.41114%	18.92720%
24	6.30	\$66,403	0.09675%	19.00564%
3	6.00	\$65,709	0.13029%	19.11117%
10	6.00	\$65,675	0.49509%	19.51164%
25	5.80	\$65,496	0.12344%	19.61100%
32	6.10	\$60,250	0.37164%	19.90976%
25	5.80	\$60,155	0.12344%	20.00862%
3	6.00	\$55,974	0.13029%	20.11284%
10	6.00	\$53,835	0.49509%	20.50835%
22	6.50	\$51,098	0.03037%	20.53250%
25	5.80	\$50,958	0.12344%	20.63059%
3	6.00	\$48,473	0.13029%	20.73400%
32	6.10	\$48,422	0.37164%	21.02859%
11	6.00	\$48,229	2.47545%	22.98349%
25	5.80	\$47,078	0.12344%	23.07856%
10	6.00	\$45,764	0.49509%	23.45939%
3	6.00	\$42,096	0.13029%	23.55911%
10	6.00	\$38,772	0.49509%	23.93756%
3	6.00	\$36,642	0.13029%	24.03666%
24	5.80	\$36,398	0.09123%	24.10597%
3	6.00	\$32,289	0.13029%	24.20485%
24	6.30	\$30,210	0.09675%	24.27818%
24	5.80	\$28,609	0.09123%	24.34726%
32	6.10	\$23,535	0.37164%	24.62842%
24	5.80	\$22,984	0.09123%	24.69719%
24	5.80	\$18,767	0.09123%	24.76589%
32	5.60	\$18,633	0.54800%	25.17817%
32	5.60	\$13,084	0.54800%	25.58819%
32	5.60	\$9,038	0.54800%	25.99597%
24	5.80	\$6,175	0.09123%	26.06348%
32	5.60	\$6,023	0.54800%	26.46866%
3	6.50	\$2,185	0.11925%	26.55634%



IRAS 3.2 [J:\DATA\QUOTE\]

File Edit View Analyze Report Special Location Options Help

Earthquake Local Conditions

Location Identifier: 1

Location Name: MITSUI FUDOSAN

Latitude: 37.7938690

Longitude: -122.4017720

Match Level: Hi-Res

Landslide: [] Match Level: Census

Liquefaction: Very Low Match Level: Census

Soil Type: Bay Mud/Artificial Fill Match Level: Hi-Res

**COMMERCIAL LINES MANUAL
DIVISION FIVE - FIRE AND ALLIED LINES
RATE PAGE**

CALIFORNIA (04)

73. CAUSES OF LOSS - EARTHQUAKE FORM

**E.1.a. Class Rated Risks - Earthquake Zones
and Rate Table (Subline Code 930)**

A. EARTHQUAKE ZONES

Zone	Territory				
3	Counties of Amador Butte Calaveras Colusa El Dorado Fresno	Glenn Kings Lassen Madera Mariposa Merced	Modoc Nevada Placer Plumas Sacramento San Joaquin	Shasta Sierra Siskiyou Stanislaus Sutter Tehama	Trinity Tulare Toulumne Yolo Yuba
1	Balance of State				

B. RATE TABLE.

per \$100 Value

	Zone 1					Zone 3					
Bldg.	Bld.	Contents Rate Grade				Bldg.	Contents Rate Grade				Mandatory
Class	Rate	1	2	3	4	Rate	1	2	3	4	Deductible
1C,2A	.143	1.19	.285	.143	.095	.072	.59	.149	.072	.049	5%
1D,2B	.238	1.19	.285	.143	.095	.112	.59	.149	.072	.049	5%
3A,4A	.285	1.19	.285	.143	.095	.137	.59	.149	.072	.049	5%
3B,4B,5A	.333	1.19	.285	.143	.095	.157	.59	.149	.072	.049	5%
3C,4C,4D,5AA	.507	1.33	.412	.269	.143	.247	.65	.215	.129	.069	10%
5B	1.00	1.43	.81	.57	.285	.455	.72	.398	.274	.131	10%
5C	1.50	2.38	1.90	1.19	.475	.68	1.15	.89	.55	.217	10%

NOTE: Requests for specific rating and publication must be submitted on Form CP 16 12 11 85 and it must be accompanied by a complete set of certified construction drawings, specifications, and available soil reports from the Design Professional and Contractor, indicating the design standards and the Building Construction Inspection Program to be utilized.

1. Policies covering exclusively on the steel frame of a building, while in the course of construction, may have a minimum deductible of 2%.

2. Deductibles may be increased to a maximum of 40%. Reduce the above rates for each percent of deductible in excess of the mandatory percentage as follows:

a. Building and Contents rates in Building Classes 1C, 1D, 2A, 2B, 3A, 3B, 3C, 4A, 4B & 5A-2%.

b. Building and Contents rates in Building Classes 4C, 4D, 5AA, 5B & 5C-1%.

3. Increase the above building and contents rates 25% for each condition applying if:

a. Buildings are located on other than firm, natural ground, (except intermediate hazard areas may be given a 10% increase).

b. A roof tank is on the building, (unless otherwise provided by rate publication).

73. CAUSES OF LOSS—EARTHQUAKE FORM
(Cont'd)

D. Rating Procedure

1. Risk Classification

a. Class Rated Risks. Refer to Rule 73.D.4. to obtain building classification description.

b. Specific Rated Risks. For any class, a request for specific rating and publication must be submitted on Endorsement **CP 16 12**. The request must be accompanied by a complete set of certified construction drawings, specifications, and available soil reports from the design professional and contractor indicating the design standards and the Building Construction Inspection program to be utilized.

2. Deductibles. All rates for property damage coverage are based on a mandatory deductible percentage of the value of the property covered. The mandatory deductible percentage and credits for higher deductible percentages are shown in the State Rates.

3. Zones. Obtain the Earthquake Zone from the State Rates.

4. Building Classification. Building classifications are as follows (any building which fully qualifies under more than one definition should be placed in the lower numbered classification):

Note: In cases of mixed construction where two or more types of construction each represent 10% or more of the total area of the building, apply the Class which produces the highest rate.

a. Completed Buildings

(1) Wood Frame Buildings. (Excluded are structures which are classified for fire as wood frame but have concrete supported floors and/or some walls of unit masonry or concrete.)

Class 1C

Habitational: Wood frame and frame stucco habitational buildings which do not exceed 2 stories in height, regardless of area.

Non-Habitational: Wood frame and frame stucco buildings which are 3 stories or less in height and 3000 square feet or less in ground floor area.

Class 1D. Wood frame and frame stucco buildings not qualifying under Class 1C.

(2) All-Metal Buildings

Class 2A. All-metal buildings which are one story in height and 20,000 square feet or less in ground floor area. Wood or cement-asbestos are acceptable alternatives to metal roofing and/or siding.

Class 2B. Buildings which would qualify as Class 2A except for exceeding area or height limitations.

(3) Steel Frame Buildings

Class 3A. Buildings with a complete steel frame carrying all loads. Floors and roofs must be of poured-in-place reinforced concrete or of concrete fill on metal decking welded to the steel frame (open web steel joists excluded). Exterior walls must be non-load bearing and of poured-in-place reinforced concrete or of reinforced unit masonry. Buildings having column-free areas greater than 2,500 sq. ft. (such as auditoriums, theaters, public halls, etc.) do not qualify.

Class 3B. Buildings with a complete steel frame carrying all loads. Floors and roofs must be of poured-in-place reinforced concrete or metal, or any combination thereof, except that roofs on buildings over three stories may be of any material. Exterior and interior walls may be of any non-load bearing material.

Class 3C. Buildings having a complete steel frame with floors and roofs of any material (such as wood joist on steel beams) and with walls of any non-load bearing materials.

(4) Reinforced Concrete Buildings, Combined Reinforced Concrete and Structural Steel Buildings. (Class 4A and 4B buildings must have all vertical loads carried by a structural system consisting of one or a combination of the following: (a) poured-in-place reinforced concrete frame, (b) poured-in-place reinforced concrete bearing walls, (c) partial structural steel frame with (a) and/or (b). Floors and roofs must be of poured-in-place reinforced concrete, except that materials other than reinforced concrete may be used for the roofs of buildings over 3 stories.)

Class 4A. Buildings with a structural system as defined above with poured-in-place reinforced concrete exterior walls or reinforced unit masonry exterior walls. Not qualifying are buildings having column-free areas greater than 2,500 sq. ft. (such as auditoriums, theaters, public halls, etc.).

Class 4B. Buildings having a structural system as defined above with exterior and interior non-bearing walls of any material.

Class 4C. Buildings having: (i) partial or complete load carrying system of precast concrete, and/or (ii) reinforced concrete lift-slab floors and/or roofs, and (iii) otherwise qualifying for Class 4A and 4B.

73. CAUSES OF LOSS—EARTHQUAKE FORM (Cont'd)

Class 4D. Buildings having a reinforced concrete frame, or combined reinforced concrete and structural steel frame. Floors and roofs may be of any material (such as wood joist on reinforced concrete beams) while walls may be of any non-load bearing materials.

(5) Concrete Brick or Block Buildings

Class 5A. One-story buildings having load bearing exterior walls of (i) poured-in-place reinforced concrete, and/or (ii) precast reinforced concrete, and/or (iii) reinforced brick masonry, and/or (iv) reinforced hollow concrete block masonry. Roofs and supported floors of wood or metal assemblies.

Class 5AA. Buildings of any height, with floors and/or roofs which may be of any material otherwise qualifying for Class 5A.

Class 5B. Buildings having load bearing walls of unreinforced brick or other unreinforced solid unit masonry, excluding adobe. Floors and roofs may be of any material.

Class 5C. Buildings having load bearing walls of hollow tile or other hollow unit masonry construction, adobe, and cavity wall construction. Also included are buildings not covered by any other class.

(6) Earthquake Resistive Buildings

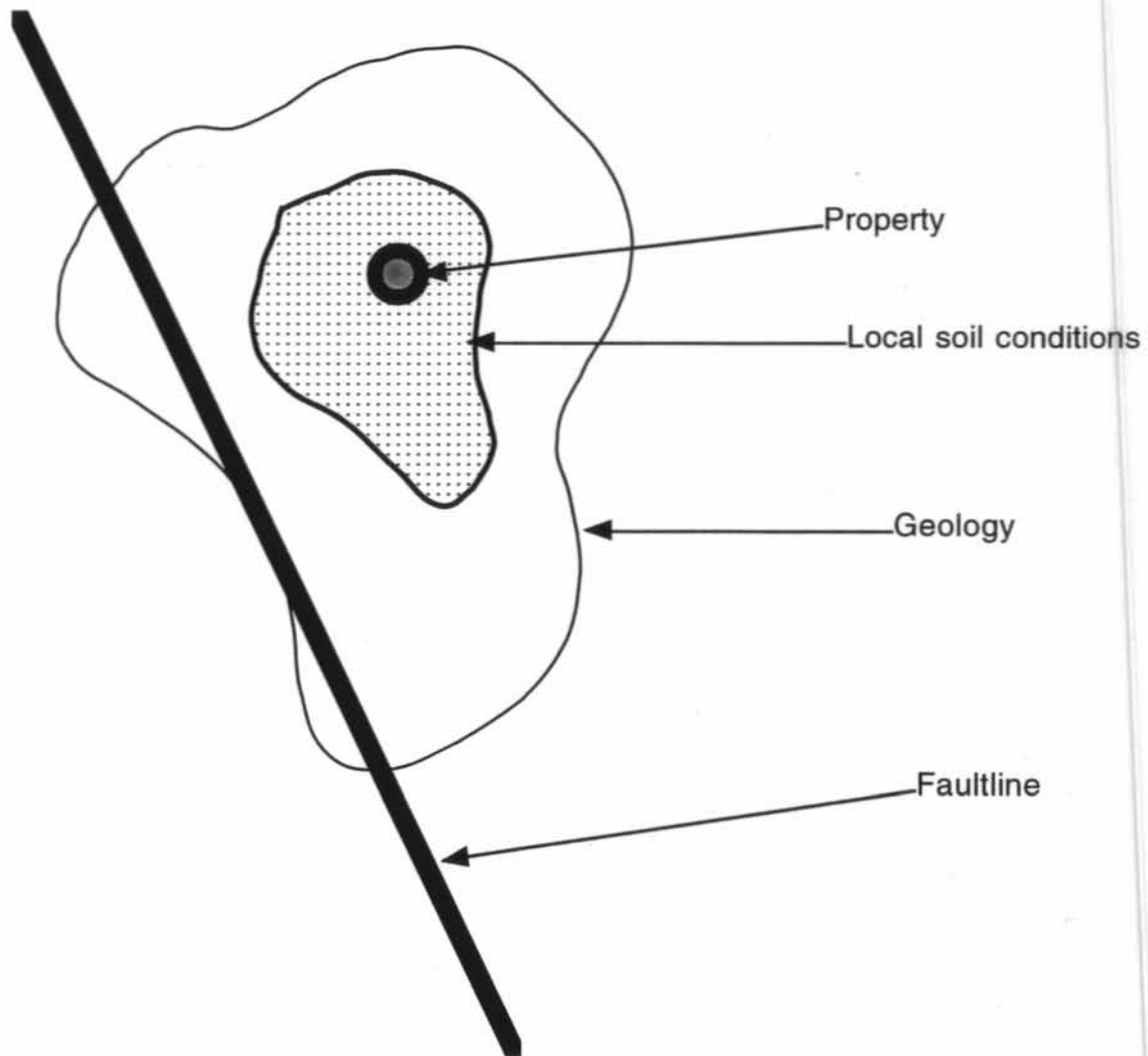
Class 6-Specific Rating Required. Any building with any combination of materials so designed and constructed as to be highly earthquake resistant; with superior damage control features in addition to meeting or exceeding the applicable seismic lateral force provision of the Uniform Building Code, Section 2312, 1979 edition or equivalent. This classification is reserved for use by ISO Commercial Risk Services, Inc.

b. Buildings in Course of Construction. All buildings and special structures during course of construction must be placed in accordance with the appropriate completed building or structure Class, except Class 3A, 4A, 5A & 6, are not applicable.

c. Class 7-Special Structures

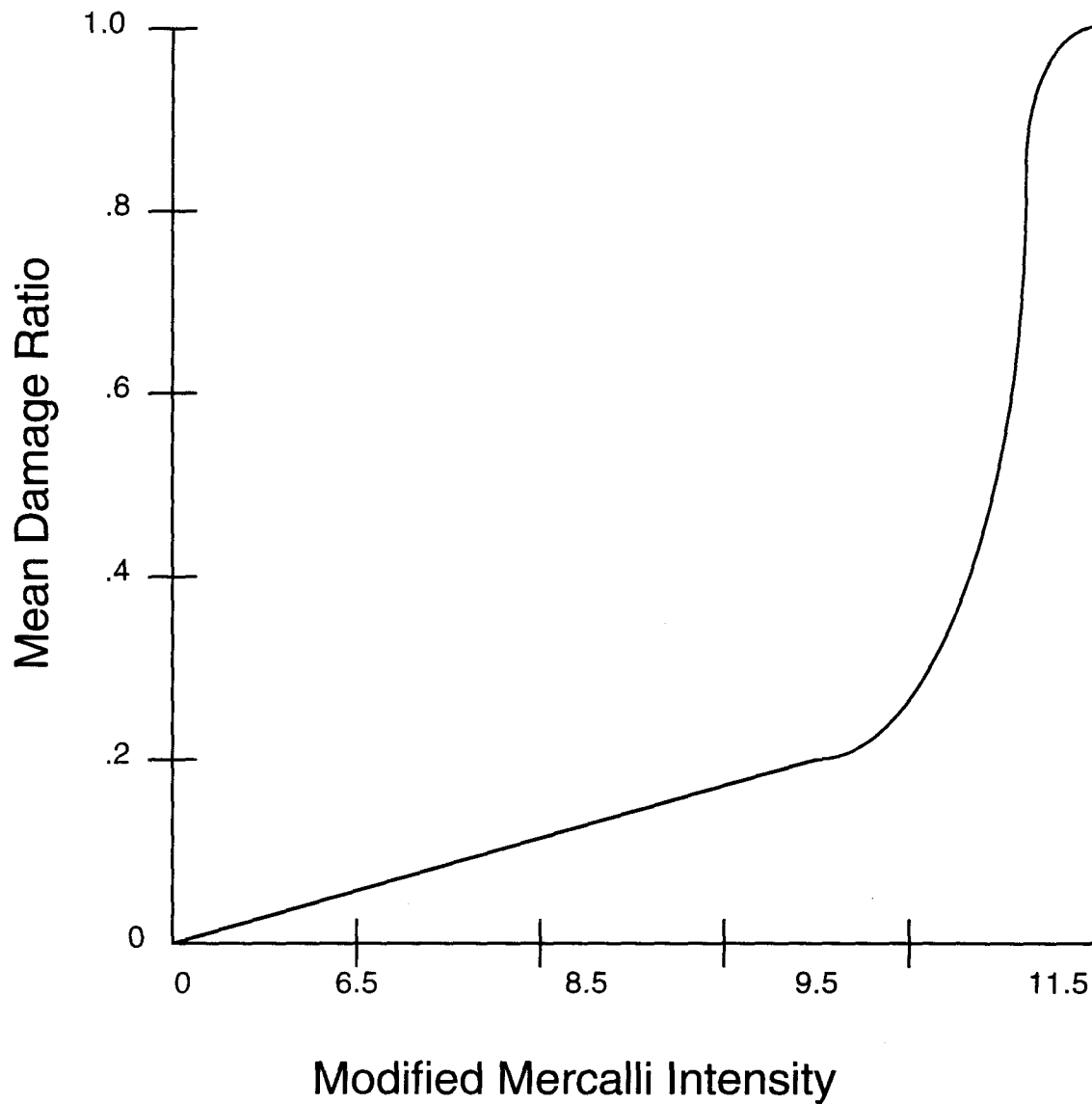
Listed on page CF-69 are special structures not qualifying as buildings; Special structures will receive the rate for the equivalent Building Classification. Class of non-listed structures may be obtained upon written application. Earthquake resistive structures of the types listed on page CF-69 may be published with a reduced equivalent building class upon submission of an application accompanied by a complete set of certified construction drawings, specifications and available soil reports.

Factors Affecting Intensity at Specific Site



1. Distance from the seismic event, it's . Intensity, and location
2. Regional Geology.
3. Local soil type.

Typical Damage Ratio Curve



- Damage Ratio is the percentage of damage of a structure as a percentage of its total value.
- The damage ratio curve depends on the type of construction.

ISO EARTHQUAKE SUSCEPTIBILITY ZONES

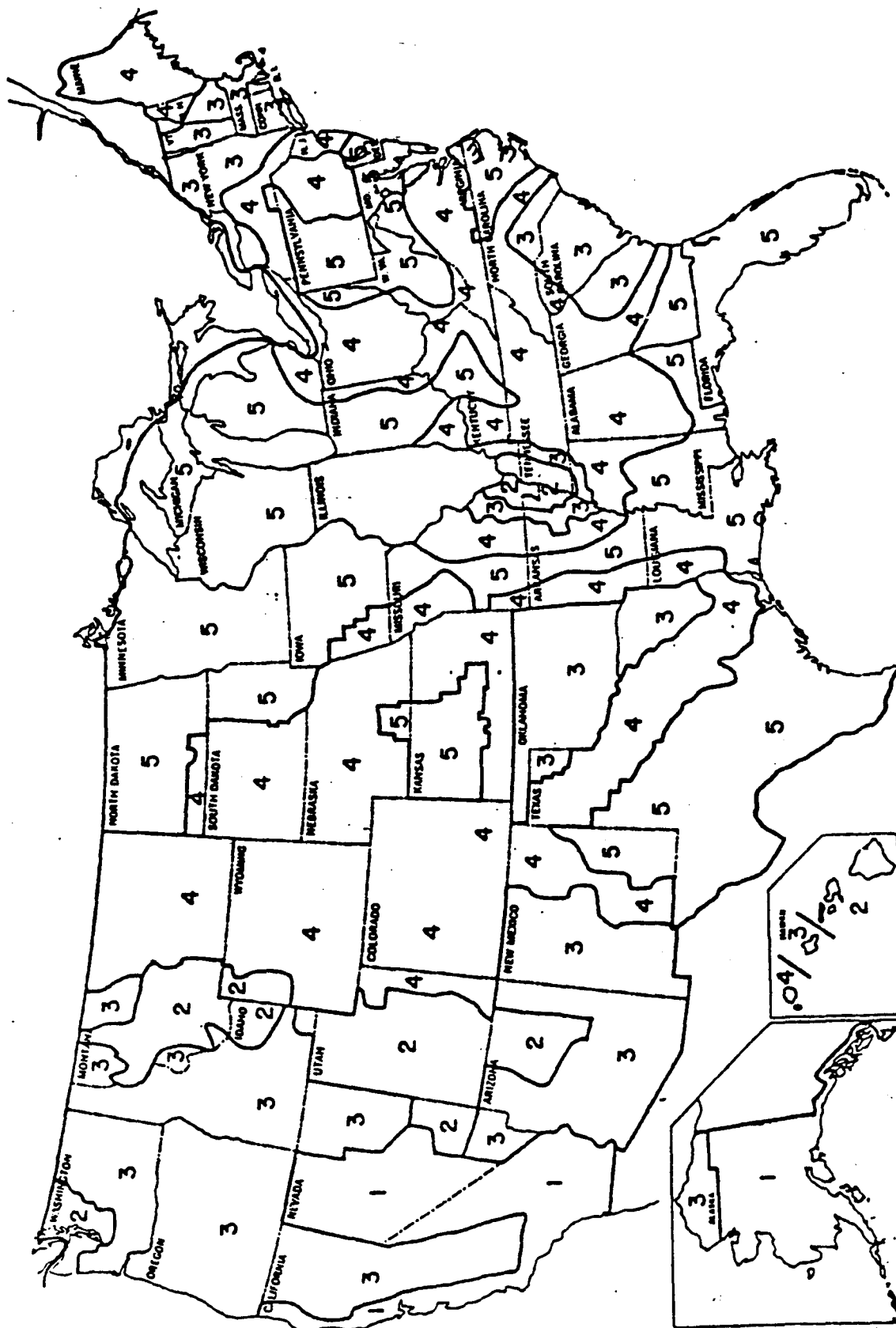


FIGURE 1

SECTION

CATASTROPHE CONTROLS: EARTHQUAKE

PAGE NO. AND

PUB/REV DATE

LOS ANGELES AREA - MAJOR EQ FAULT LINES

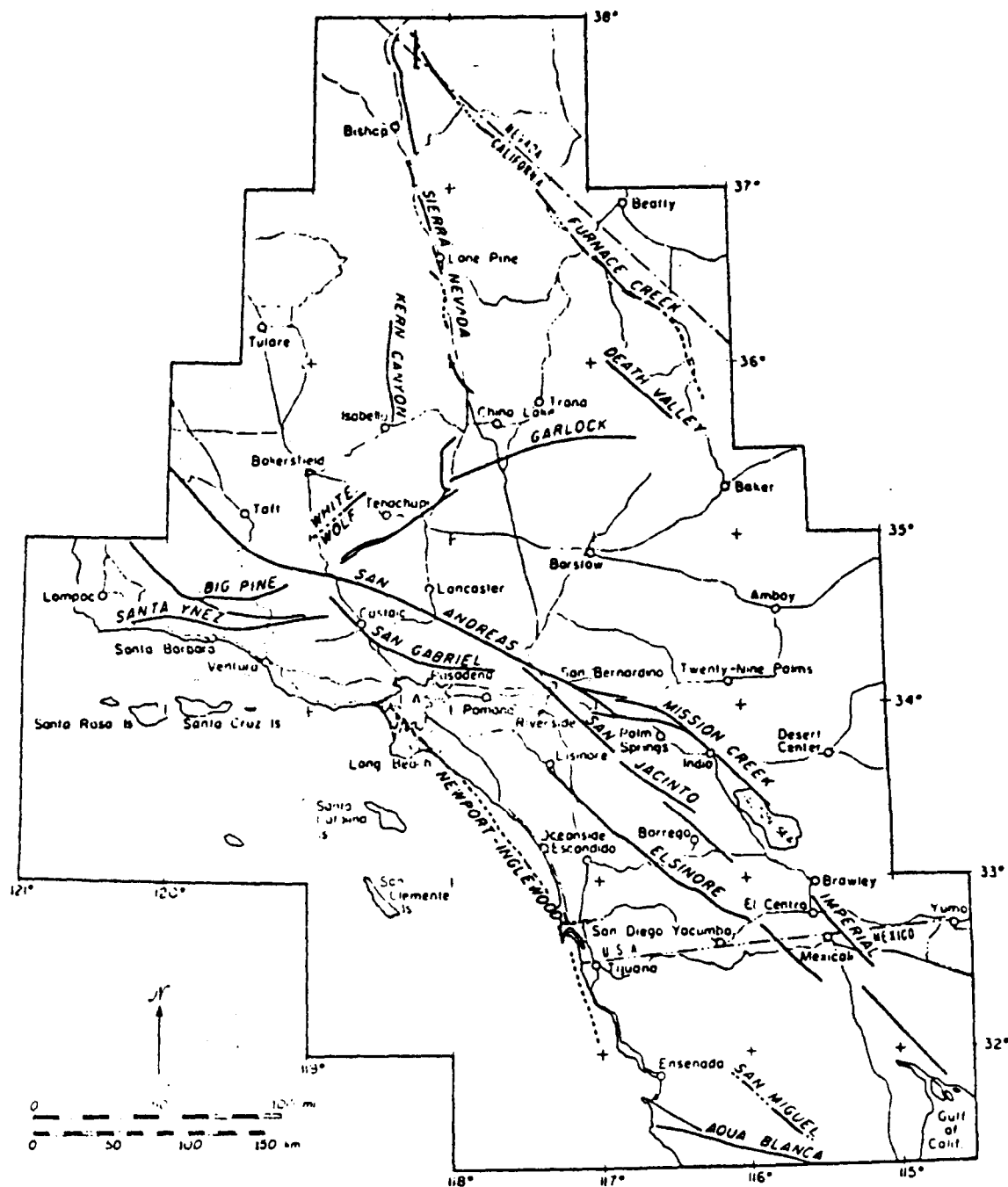


FIGURE 2

SECTION

CATASTROPHE CONTROLS: EARTHQUAKE

PAGE NO. AND

PUB/REV DATE:

4

May 1, 1985

SAN FRANCISCO AREA - MAJOR EQ FAULT LINES

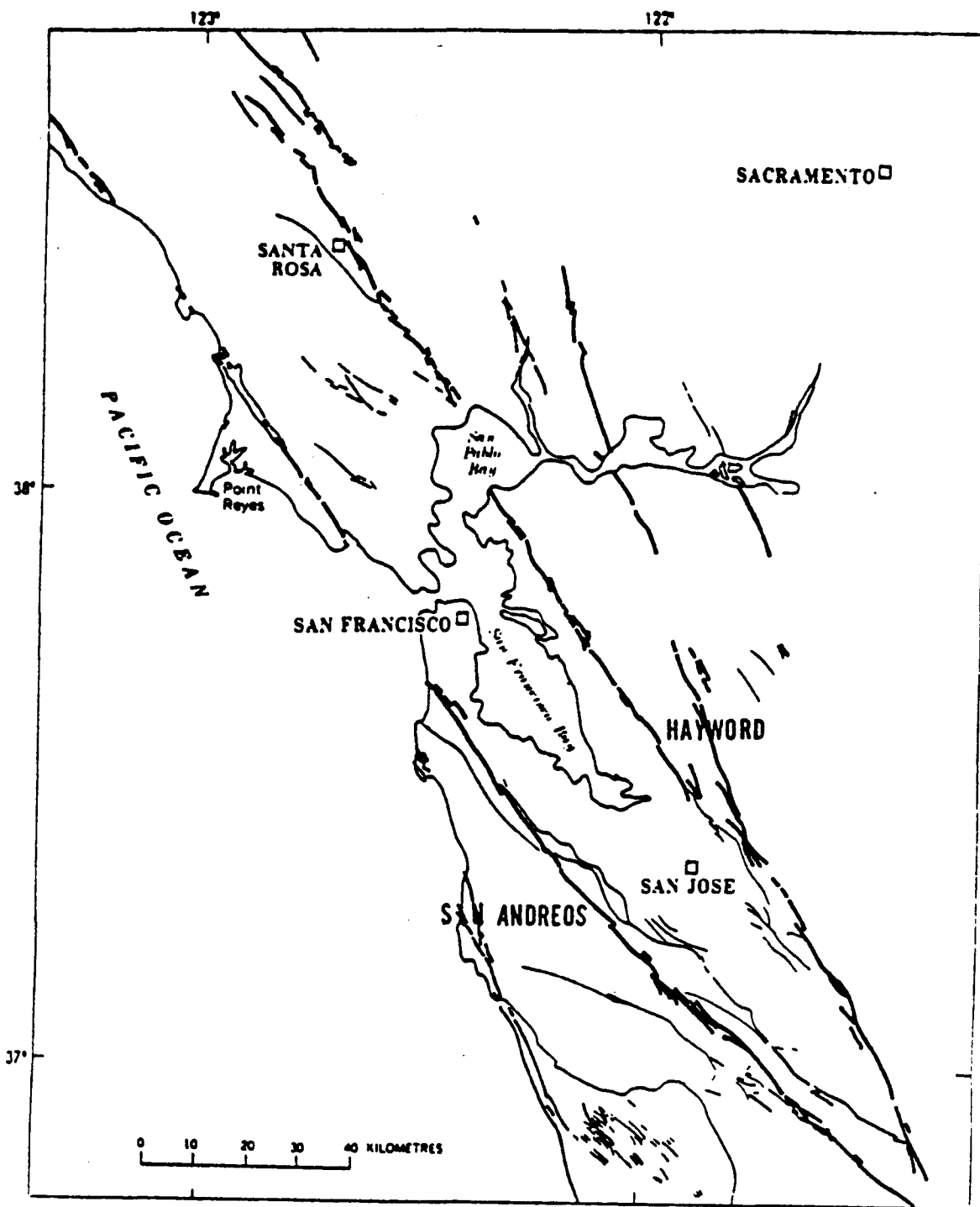


FIGURE 3

SECTION

CATASTROPHE CONTROLS: EARTHQUAKE

PAGE NO. AND
PUB/REV DATE

References

- Bock, Yehuda, 1994. Crustal Deformation and Earthquakes, *Geotimes*, vol 39, No 6.
- Dewey, James W., 1994. *Earthquakes and Volcanoes*, vol 25, No 2.
- Hauksson, Egill, and Lucile M. Jones, 1994. Seimology: The Northridge Earthquake and It's Aftershocks, *Earthquakes and Volcanoes*, vol 25, No 2.
- IRAS Version 3.0., 1993. Risk Management Software Inc., Mountain View CA.
- IRAS Version 3.0, User's Manual, 1994. Risk Management Software Inc., Mountain View CA.
- Johnston, M.J.S. and R.J. Mueller, 1987. Seismomagnetic Observation During the July 8 1986 Magnitude 5.9 NorthPalm Springs Earthquake, *Science*, Sept 4, vol 237.
- Lomnitz, Cinna, 1994. *Fundamentals of Earthquake Prediction*. John Wiley and Sons, Inc. New York .
- The Jan 17, 1994, Northridge, CA Earthquake, 1994. EQE Summary Report, March 1994.
- Quake Prediction Tool Gains Ground, 1995. *Science*, Nov 10, vol 270.
- Tazieff, Haroun, 1992. *Earthquake Prediction*. McGraw Hill Inc., New York.

Tullis, Terry E., 1994. Predicting Earthquakes and the
Mechanics of Fault Slip, *Geotimes*, vol 39, No 7.

Varotsos, P., and M. Lavaridoy, 1991. Latest Aspects of
Earthquake Prediction in Greece Based on Seismic
Electrical Signals, *Tectonophysics*, 188.